

Figure 2. The **Moving AFM Tip** would deposit the outflow of a microchromatography column along a microchannel. After subsequent evaporation of the solvent, the AFM could be used to profile the deposited analytes.

by conventional AFM profiling.

*This work was done by Mark Anderson of Caltech for NASA's Jet Propulsion Laboratory.*

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## Model of Image Artifacts From Dust Particles

**This first-order geometric-optics-based model yields realistic predictions.**

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A mathematical model of image artifacts produced by dust particles on lenses has been derived. Machine-vision systems often have to work with camera lenses that become dusty during use. Dust particles on the front surface of a lens produce image artifacts that can potentially affect the performance of a machine-vision algorithm. The present

model satisfies a need for a means of synthesizing dust image artifacts for testing machine-vision algorithms for robustness (or the lack thereof) in the presence of dust on lenses.

A dust particle can absorb light or scatter light out of some pixels, thereby giving rise to a dark dust artifact. It can also scatter light into other pixels,

thereby giving rise to a bright dust artifact. For the sake of simplicity, this model deals only with dark dust artifacts. The model effectively represents dark dust artifacts as an attenuation image consisting of an array of diffuse darkened spots centered at image locations corresponding to the locations of dust particles. The dust artifacts are computa-

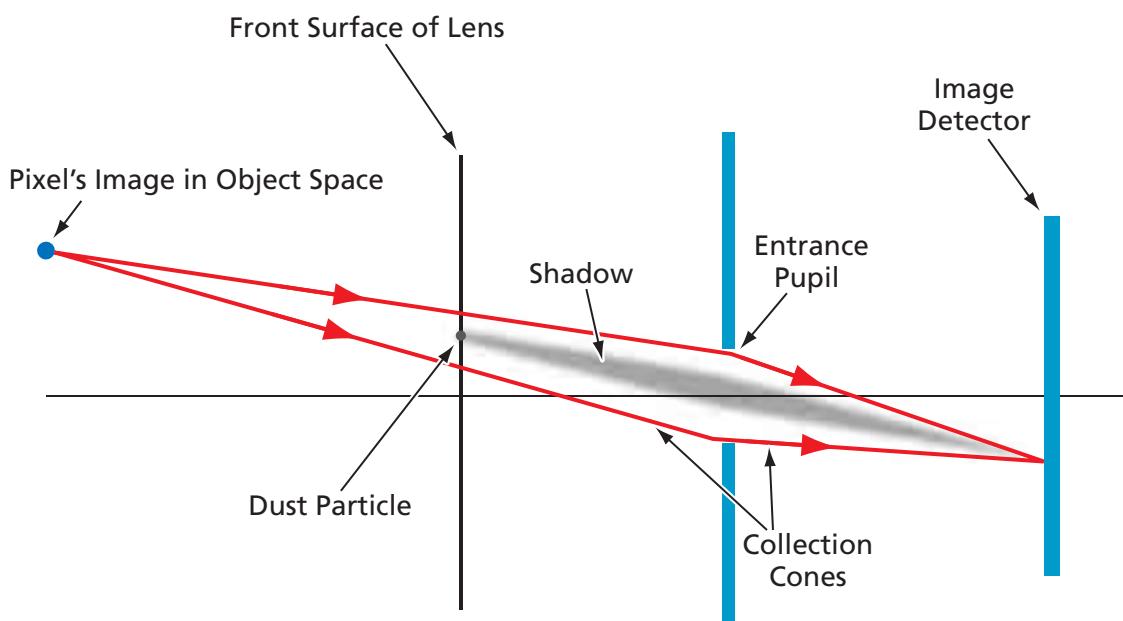
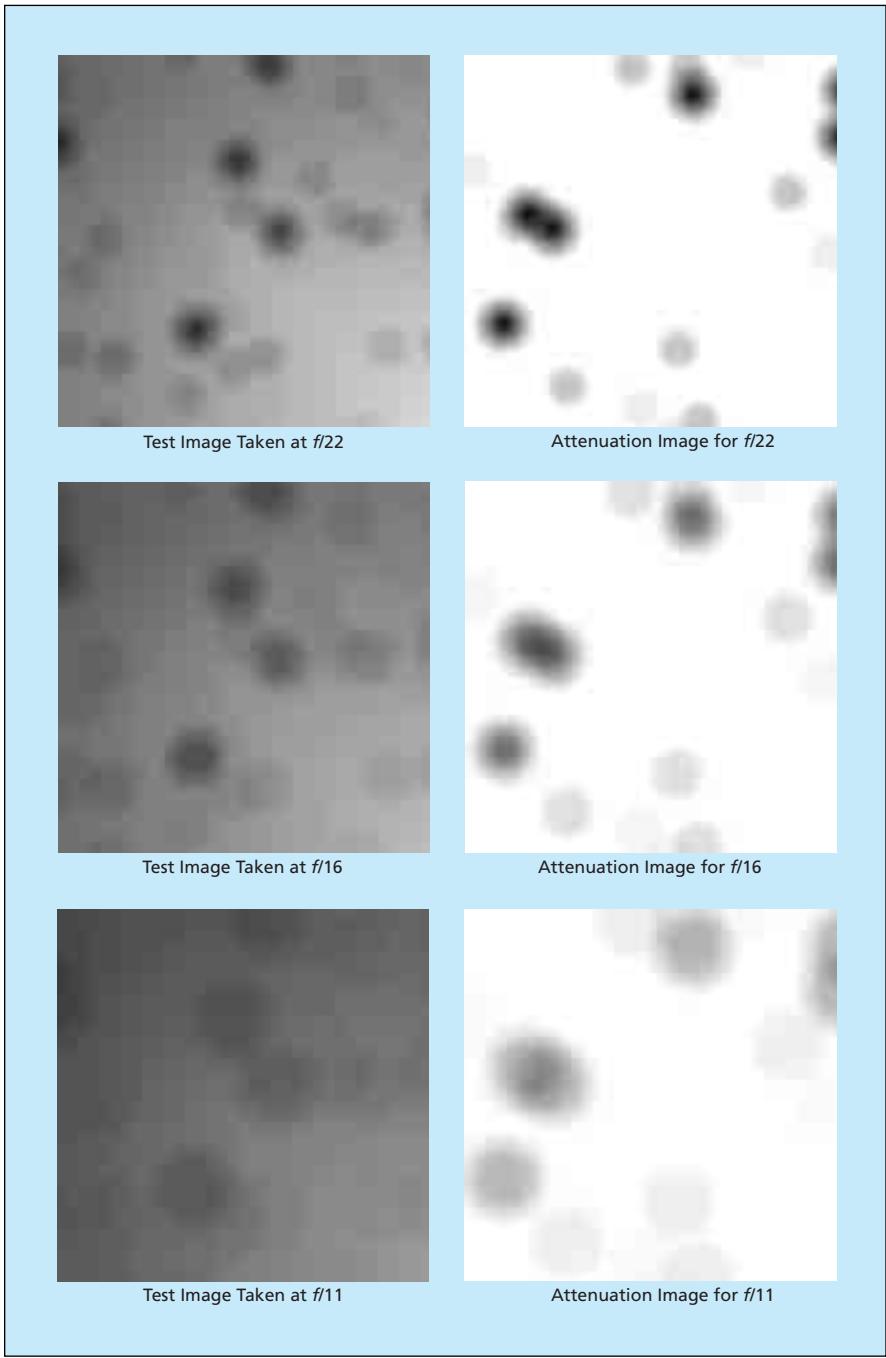


Figure 1. A **Geometric-Optics Model** of shadowing is used to compute the effects of dust particles on an image.



**Figure 2. Test Images Containing Dust Artifacts** recorded at various relative apertures are shown alongside the corresponding synthetic attenuation images.

tionally incorporated into a given test image by simply multiplying the brightness value of each pixel by a transmission factor that incorporates the factor of attenuation, by dust particles, of the light incident on that pixel.

With respect to computation of the attenuation and transmission factors, the model is based on a first-order geometric (ray)-optics treatment of the shadows cast by dust particles on the image detector. In this model, the light collected by a pixel is deemed to be confined to a pair of cones defined by the location of the pixel's image in object space, the entrance pupil of the lens, and the location of the pixel in the image plane (see Figure 1). For simplicity, it is assumed that the size of a dust particle is somewhat less than the diameter, at the front surface of the lens, of any collection cone containing all or part of that dust particle. Under this assumption, the shape of any individual dust particle artifact is the shape (typically, circular) of the aperture, and the contribution of the particle to the attenuation factor for a given pixel is the fraction of the cross-sectional area of the collection cone occupied by the particle. Assuming that dust particles do not overlap, the net transmission factor for a given pixel is calculated as one minus the sum of attenuation factors contributed by all dust particles affecting that pixel.

In a test, the model was used to synthesize attenuation images for random distributions of dust particles on the front surface of a lens at various relative aperture (F-number) settings. As shown in Figure 2, the attenuation images resembled dust artifacts in real test images recorded while the lens was aimed at a white target.

*This work was done by Reg Willson of Caltech for NASA's Jet Propulsion Laboratory.*

*The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-42437.*